THE FREQUENCY VARIATION OF THE INTENSITY OF LOW-LATITUDE WHISTLER WAVES

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Abstract

In order to have further understanding on the whistler propagation mechanism, we have developed a new spectrum analyzer using PCM recorders and an FFT analyzer. By using this equipment, we can investigate easily the fine structures of whistler spectra, especially the intensity change with frequency of whistlers. We have found the "Patched" whistlers, not similar variations appearing in the frequency spectrum of the sources, and presented experimental characteristics. As an interpretation of these patched whistlers observed at Yamaoka (Geomag. lat. 25°N), we have theoretically calculated the transmission coefficients of whistler waves propagating downward through the irregular F layer in the ionosphere, and compared with the experiments.

1. Introduction

A lightning discharge radiates electromagnetic waves over a wide range of frequencies. Whistlers are the VLF electromagnetic waves propagate through the ionosphere and magnetosphere originating in this discharge in the opposite hemisphere. A brief study of the relation between the spectrum of the causative atmospheric and the resulting whistler was made by Helliwell et al.(1965). It was found that the spectrum of whistler source measured at the receiver in this experiment peaked near 5kHz and the total electromagnetic energy was about ten times as great as that in the average lightning flash. Therefore it is probable that the intensity variations of most whistlers are controlled largely by the spectrum of the source. So each component of whistler should show roughly the same spectral peaks.

We have developed a new spectrum analyzer using PCM recorders and an FFT analyzer. By using this equipment, we can investigate easily the fine structures of whistler spectra, especially the intensity change with frequency of whistlers. We have found "Patched" whistlers, which exhibit a patched structure in the spectra (Tian et al., 1988). An example observed Jan. 12 in 1987 at Yamaoka (Geomag. lat. 25°N) is shown in Fig.1. In Fig.1 the dispersion of whistlers are 30 $sec^{1/2}$ which is typical daytime whistles observed at Yamaoka. The intensity of whistlers are drown as the contour lines of eight stages. In order to reject the noise from power line and the transmitter of VLF, the band pass filter of 2-6kHz is included in the amplifier of the equipment. So the signal from 2 to 6kHz is detected strongly. The source C1 corresponds to the whistler W1, and C2 corresponds to the W2 respectively. The whistler W1 and W2 have same "Patched" structure in the spectra regardless of the different source. High intensity frequency parts in the spectra are 7.75, 7.0, 5.75, 5.0, 4.25, 3.0 and 2.25kHz.

We obtained some preliminary important results as follows:

(1) The pure-tone whistlers observed at low latitude Yamaoka are almost patched whistlers.

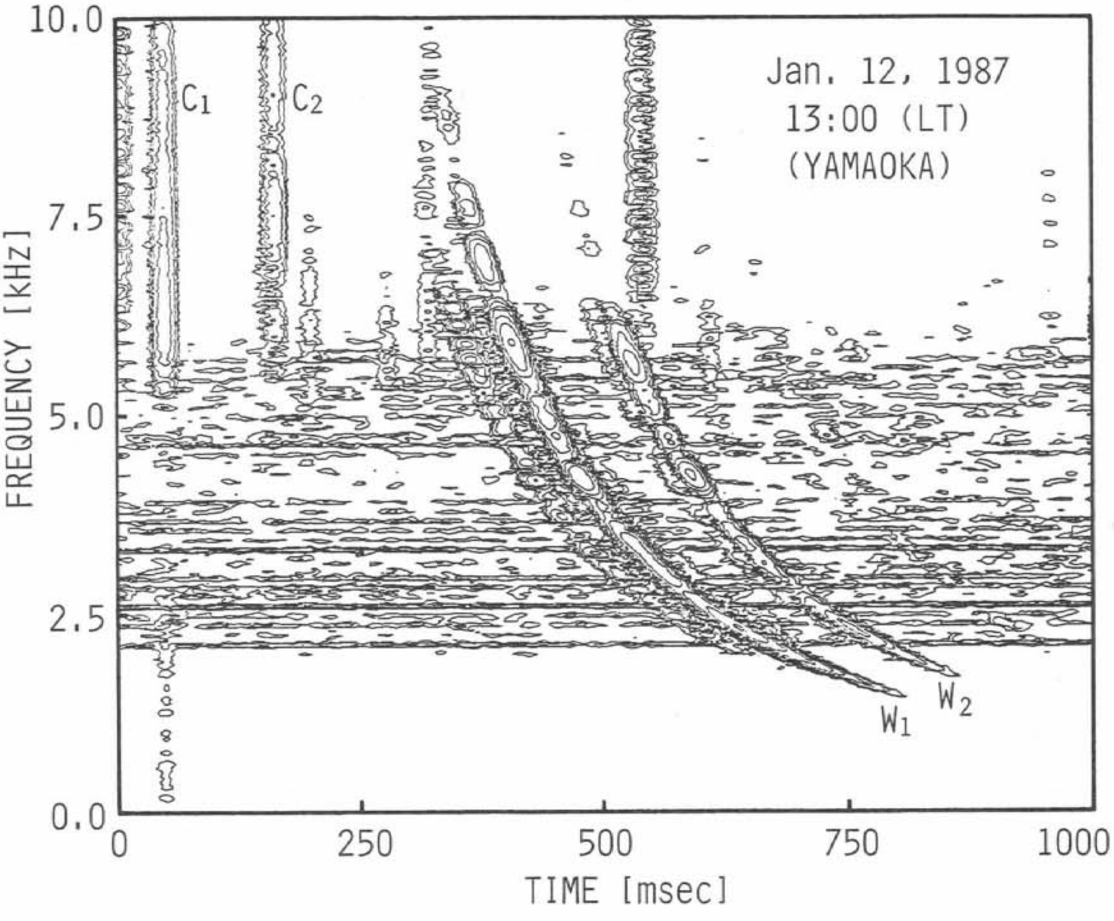

Fig.1 An example of the frequency spectrum of daytime whistlers exhibiting patched structure.

(2) The patched whistlers show different spectrum of the sources.
(3) The spacing of successive positions of intensity null (or maxima) is very variable and during a short time interval (the order of 1 sec.), the patched frequencies are the same, but after a few seconds they become very different from the previous one.
(4) The spacing of successive positions of intensity null (or maxima) is from 200Hz to 2.5kHz.
(5) Not only in daytime but also in nighttime (Hayakawa, 1978), we could observe patched whistlers.

2. Some interpretations

The causes for patched whistler are considered into the following parts (Paymar, 1972):

(1) superposition of multiple signals,
(2) banding in the source spectrum,
(3) specular reflection or transmission.

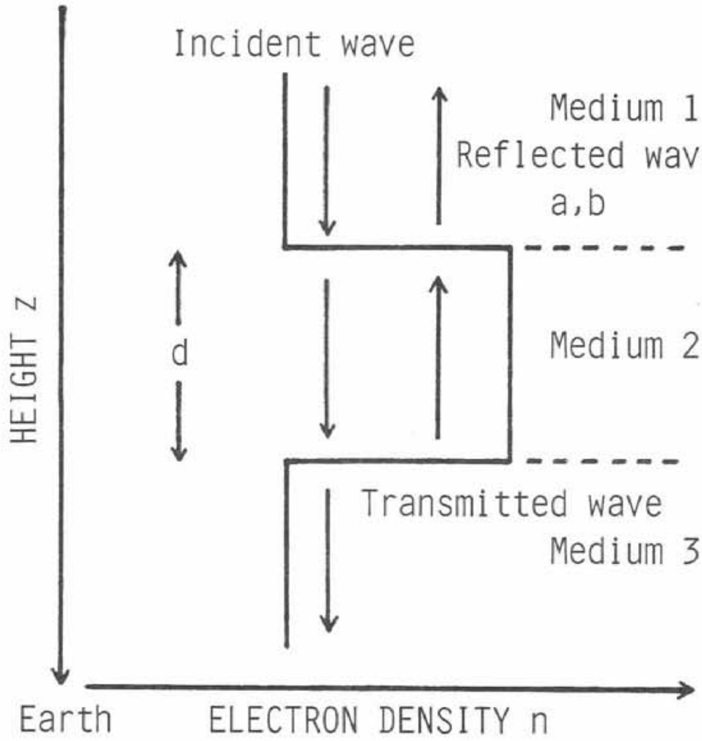

Fig.2 The model of three layers in the F region, simulating a F region irregularity.

In order to interpret the patched whistler observed at Yamaoka, we tried to calculate the transmission coefficients of whistler waves propagating through the lower ionosphere by using a full wave numerical method. But we could not explain the phenomenon of patched structure (Tian et al., 1988). So we are obliged to think of other kind of wave interference mechanism such as irregularities in F layer. We added the spread F ionization on the background electron density in Fig.2. We have theoretically calculated the transmission coefficients of whistler waves propagating downward through the irregular F layer in the ionosphere.

The height of Medium 2 is a slab of depth d whose density is n2, enhanced by irregularities. The terms "a" and "b" are the "ordinary mode" and "extraordinary mode" respectively (Budden, 1961). We assume that incident wave on the condition of "a mode" at Medium 1 is going vertically downwards. Because the ionospheric exit points of whistler are highly concentrated with in a radius of 20km around the zenith of the station of Yamaoka (Ohta et al., 1984, Hayakawa et al., 1985). We have theoretically calculated the transmission coefficients of whistler wave at Medium 3 propagating downward through the irregular layer of Medium 2. In Fig.2 we assume that the background electron density of Medium 1 and Medium 3 are 10^6 /cm^3 and the height of Medium 2 is 300km from the earth.

The frequency dependence of transmission coefficients of transmitted "a mode" wave with the condition of d=0.5km, n2=10×10^6 /cm^3 is shown in Fig. 3. We can get very clear oscillations in the transmission coefficients with frequency.

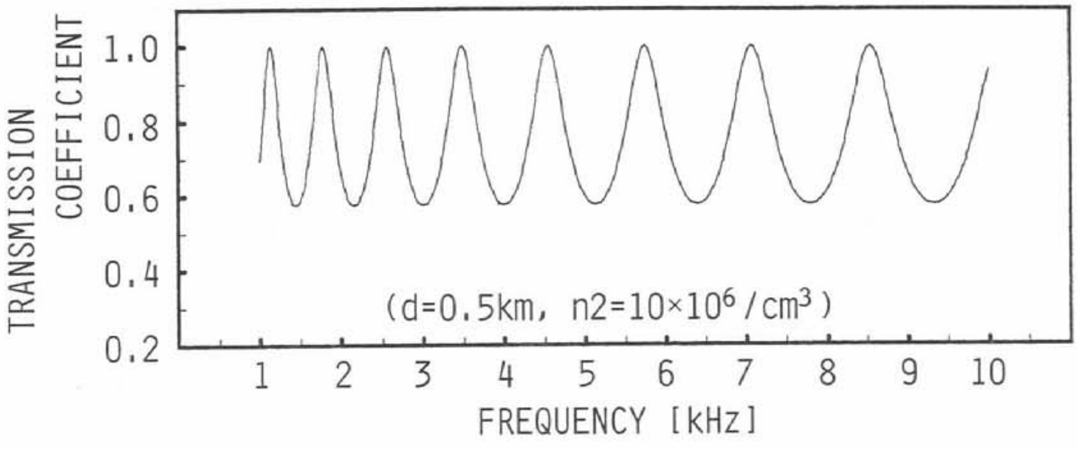

Fig.3 Transmission coefficients of downgoing whistlers for $d=0.5km$, $n2=10\times10^6\ /cm^3$.

3. Conclusion

In order to interpret the patched structure of daytime whistlers observed at Yamaoka, we tried to calculate the transmission coefficients of whistler waves propagating trough the irregularities in the F layer. We can get very clear oscillations in the transmission coefficients with frequency at wide frequency range. So the results obtained are very much in agreement with the patched whistlers observed at Yamaoka that the results may be able to explain the patched whistlers.

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